REVERSE BEHAVE FUEL MODELING AND FIRE PREDICTION SYSTEM FOR PRESCRIBED FIRE PLANNING

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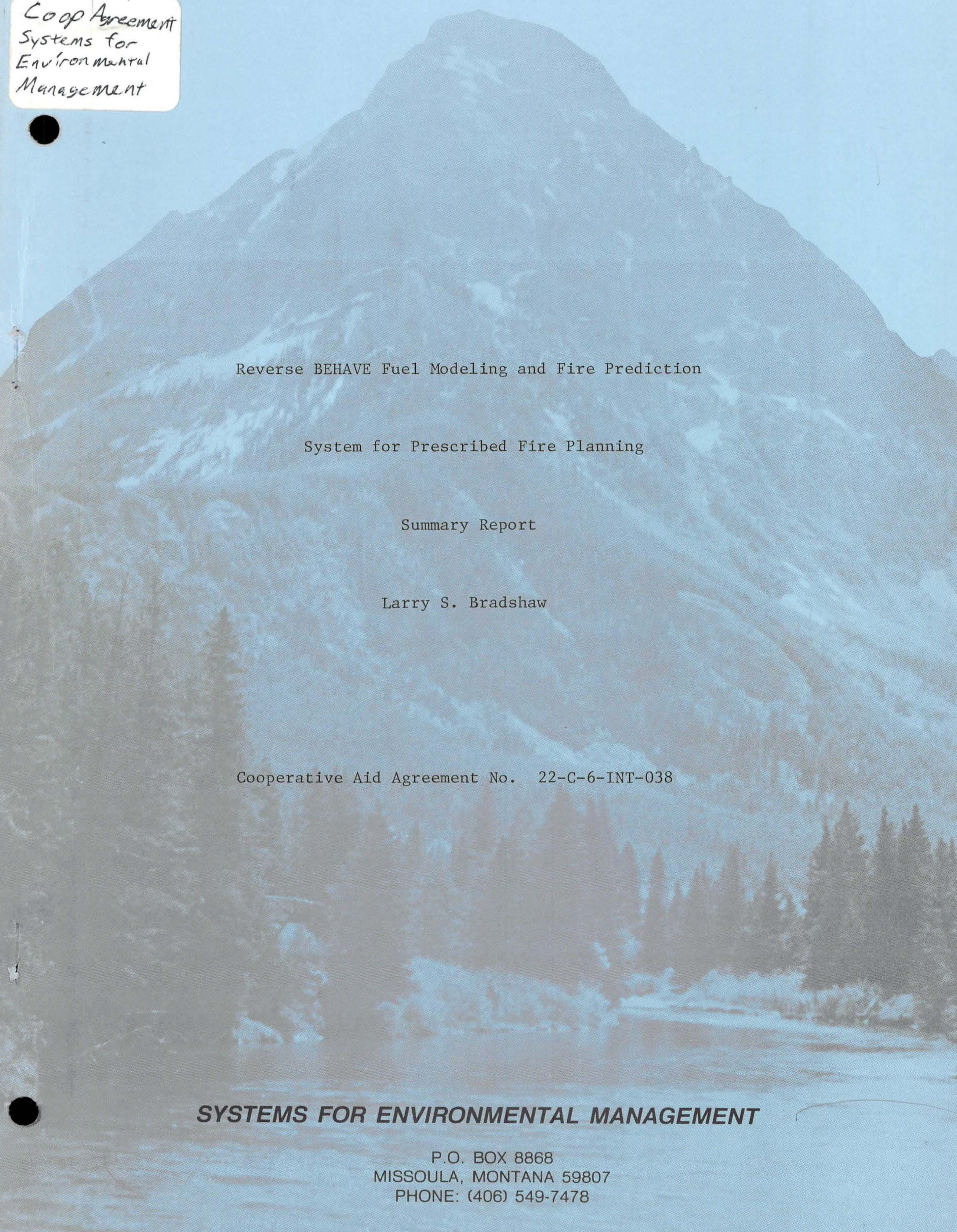

Reverse BEHAVE Fuel Modeling and Fire Prediction

System for Prescribed Fire Planning

Summary Report

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Cooperative Aid Agreement No. 22-C-6-INT-038

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

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SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

A Natural Resources Research Group

Systems for Environmental Management (SEM) is a non-profit research and educational corporation based in Missoula, Montana, a regional center for natural resources agencies. Founded in 1977, SEM works cooperatively and under contract with the U.S. Forest Service, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs, as well as state and academic institutions, private individuals and organizations.

SEM's diverse professional staff offers a wide range of research capabilities within the natural resources management field. The full-time staff includes specialists in fire behavior, fire history, recreation management, geography, plant ecology, forestry, meteorology, data analysis, and computer science. SEM also maintains a pool of professional affiliates that can be utilized for projects requiring additional expertise. Areas of recent research emphasis include wilderness recreation management, fire history and ecology, fire planning, and development of computerized resource management tools.

Introduction

This report is submitted in fulfillment of sections II and III, paragraphs C of cooperative aid agreement No. 22-C-6-INT-038, amended, entitled "Reverse BEHAVE Fuel Modeling and Fire Prediction System for Prescribed Fire Planning" between the Intermountain Fire Sciences Laboratory, and Systems for Environmental Management, Missoula, Montana. The report is a more technical companion to a proceedings paper (appendix A) which will be presented at the Ninth Conference on Fire and Forest Meteorology in San Diego, California. It is suggested reading prior to this report.

Our objective was to investigate methods for reversing the computational process in the fire behavior model (Rothermel 1972) and develop a prototype system that, given a static fuel/topography scenario and desired fire behavior characteristics, one may view windows of environmental conditions conducive to conducting successful burns. Our prototype program, WINDOW, is limited to the mathematical models employed in the DIRECT model of the BEHAVE Fire Behavior Prediction and Fuel Modeling System (Andrews 1986). The search algorithms developed for WINDOW are appropriate for providing prescription windows in a comprehensive fire prescription development system being developed (Brown and Fisher 1986) at the Intermountain Fire Sciences Laboratory (IFSL).

Four sections comprise this report. The first summarizes a user needs survey conducted as a preliminary task. The basis of the program, mathematical models and specific assumptions required for implementing our design are addressed in the second section. The third overviews the operation of the program, and the last outlines future directions.

Needs Survey

We conducted an informal survey of prescribed burners across the United States. We asked what they currently use to estimate fire behavior while planning prescribed fires; their attitudes about current fire effects and fire behavior modeling techniques; exposure and access to computers; formats they'd like their tools in; and background information on their experience, training, and burning practices. We also asked about their exposure to various fire related computer programs and databases; which fire related training sessions they found most useful; and gave them an open forum to expound on automated methods that could help in their jobs.

Survey recipients were derived from several sources. Phil Range (BLM, WO) gave us a contact person for each state BLM office and Rod Norum (NPS, BIFC) sent a list of BIA, NPS, and Fish & Wildlife Service (FWS) contacts. Jim Lundsford (USDA, FS Region 8) provided a list of active prescribed fire users in the Southeast and Patricia Andrews (IFSL) suggested numerous contacts throughout the country. Table 1 summarizes our response profile.

Table 1: Agency Distribution of Prescribed Fire Surveys

Agency	Sent	Returned	Rate	Plans
Forest Service	46	28	61%	6
BLM	14	11	79%	3
States	12	10	83%	2
NPS	9	6	67%	2
FWS	4	3	75%	1
University	8	3	38%	0
Private	2	2	100%	1
BIA	3	2	67%	1
	98	65	66%	16

Fire suppression experience for respondents averaged 18 years with quartile

values of 12, 18, and 24 years. Prescribed burning experience was slightly less at 13 years for an mean value, and quartiles of 10, 11, and 16 years. Four fifths have been to five or more training sessions in the last 10 years; ninety percent have had some fire-related computer training. Fire behavior courses at Marana, almost any 'hands on' training, and the 'S' courses were cited as the more useful fire related training events. Appendix B contains a list of survey recipients, the cover letter, and a survey with tabulated result. Also in appendix B are remarks for 'other' and 'please explain' comments in questions 7 (fire pattern use) and 18 (need for system).

We received 16 example burn plans from seven different agencies. Most plans are quite complete; they have clearly laid out objectives, fire behavior needs, firing plans, contingency and safety plans, and mop-up needs. Several plans have good economic documentation, and one presented a success/risk probability analysis. Many attached fire behavior worksheets derived from TI-59 forms, BEHAVE outputs, and nomograms as support for their fire behavior prescriptions. Prescribed fire planners are already using the 'window' concept in their plans; they'd like an easier way to do it.

We asked about prescriptions parameters; aspects of fire behavior/effects; ignition method and pattern. The five top ranked values are shown in table 2.

Table 2: Ranking of Parameters by Frequency Selected for Questions 4, 5, and 8

	Rx Parameters	Fire Behavior	Ignition Method	Ignition Pattern
1	Wind Speed	Burn Objectives	Hand Drip Torch	Strip Head
2	Rel. Humidity	Flame Length	Heli-torch	Strip Backing
3	Temperature	Spread Rate	Flares/Fusees	Flank Fire
4	Fine FM	Spotting Poten.	Propane Torch	Center/Ring
5	Wind Direct	Scorch Height	Ping-Pongs	Spot Fire

Eighty-two percent use ignition pattern to manipulate fire behavior most or

all of the time; one person rarely used ignition pattern to control fire behavior (all pile burns). Desired fire behavior, burn objectives, personal experience, and pattern of ignition were the most important parameters considered when developing a burning prescription; fuel inventory and method of ignition were deemed the least important. Personal experience, TI-59, BEHAVE and the HP-71B were used most often for fire behavior estimates. Local guidelines, the 1978 NFDRS, and nomograms were the least used. One person reported using the 1972 NFDRS.

Two-thirds felt current methods were sufficient for developing burning prescriptions. Opinions were mixed about the adequacy of current fire behavior models when applied to prescribed fire planning; however, the need for incorporating patterns of ignition were consistently mentioned. Two-thirds felt current fire effects knowledge was inadequate for developing systems using fire behavior-fire effects relationships as a primary input. The need for fire effects models and clearinghouses of fire effects information were often noted.

Most felt a system such as window could be quite useful; three quarters wanted it as a BEHAVE subsystem. Handhelds were the most desired format, followed by access on microcomputers and Data General Systems. Non-computer formats (notebooks, tables, and nomograms) were least popular.

When queried about the usefulness of information that could be provided by the system, a simple window of wind speed/direction and fuel moisture was deemed as the most useful information the system could provide. Linking the window to meterological profiles was next in usefulness. The display of weather profiles in a climatic probability format was considered very useful, but less useful than the weather profile itself. Spotting potential and probability of ignition prescription constraints were generally not perceived to be

as useful as the window and weather information.

In the open forum, suggestions ranged from a simple user friendly program that just spits out windows to elaborate systems that would integrate GIS systems, fuel maps, and ignition patterns. However, one thread ran through many suggestions: the need for a consolidation of all the fire behavior, fire weather, and fire effects models and databases into common access format.

In summary, four needs were identified:

-- Methods for incorporating different patterns of ignition into fire behavior prediction processes;

-- A program to let technology to the repetitive work now required for developing windows;

-- A clearinghouse for sharing fire behavior-fire effects information, models, and documentation of prescribed fires.

-- "One-stop-shopping" access to fire management programs and databases.

System Basis, Models, and Assumptions

Figure 1 displays some models currently available in the BEHAVE system (not just the DIRECT module), their relationships with each other, and the information required to use them.

To work this process backwards is not a trivial solution. The design of the mathematical fire model precludes straight mathematical solution so we must optimize a linear solution. The variables in the DIRECT module of BEHAVE can be simplified to the interactions in figure 2, which provides the overall basis of the program: The 10 input values required by DIRECT are reduced to three intermediate values before the final fire behavior calculations are done. The value of this, is that singular values for effective wind, weighted dead and

Figure 1. Inputs, Models, and Output of BEHAVE.

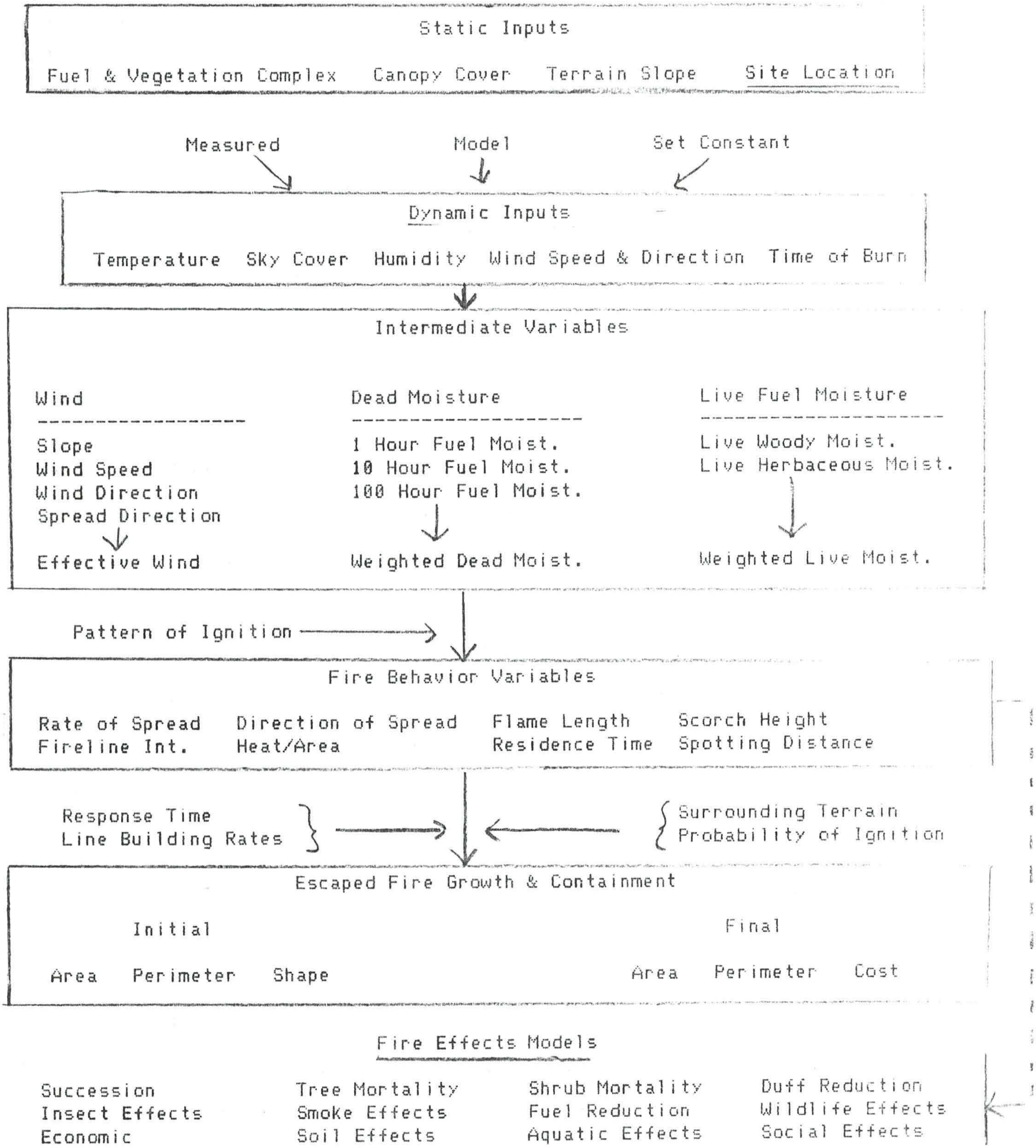

Figure 2. Basic Input, Intermediate Variables, and Output From DIRECT

Basic Input	Intermediate Variables	Predicted Fire Behavior
(1) Fuel Model (2) 1-h FM (3) 10-h FM (4) 100-h FM	Weighted Dead FM	
(1) Fuel Model (5) Live Herb FM (6) Live Woody FM	Weighted Live FM	ROS FL
(1) Fuel Model (7) Midflame Wind (8) Slope (9) Wind Direct. (10) Spread Direct.	Effective Wind	

weighted live fuel moistures can be used to predict fire behavior, and in a separate process, combinations of basic input values in figure 2 that result in critical weighted or effective values can be tabulated. The results of this are twofold. First, three single values result in many thousands less iterations of the fire model to find all the solutions for a given input set. Consider the most complex case-- three classes of dead fuel and two classes of live fuels; limit the dead fuel moisture from 5 to 20 percent; the live from 70 to 300 (steps of 10); the wind from 0 to 20; and a fixed slope. Straight linear solution could take up to 67,436,544 iterations (16*16*16*28*28*21), while the weighted method could take up to 9,408 iterations (16*28*21) -- four orders of magnitude less! Second, reducing the interaction of ten input

parameters to a manageable three allows easier representation of the solution sets.

This whole process is not quite as straight forward as it sounds, and it took a couple of reasonable assumptions.

Effective Wind Speed

Mathematically, slope has an effect on fire behavior similar to wind. Effective wind is the combined effect of atmospheric and 'slope' induced wind. Given a fuel model and constant fuel moisture values, numerous combinations of wind speed, wind direction, and slope may yield the same 'effective' wind speed, and thus the same predicted fire behavior.

Getting wind speed and direction from effective wind is intuitive, but requires two assumptions. First, the slope is known and constant, and second, the fire behavior from the computations above were within the reliable limits of the fire behavior model limitations. This is reasonable for prescribed fires, which are usually conducted at the lower range if fire severity. The basis: effective wind in a given direction is a function of fuel bed parameters, and the ratio of rate of spread in the maximum direction to rate of spread in a specific direction, so the relation between effective wind in the maximum direction and effective wind in a given direction should be the same ratio. It turns out the algebra is rather complex, (see appendix C) but what we end up with is the ability to describe the effective wind for any combination of wind speed, wind direction, and direction of fire spread (head, flank, or back fires) with out having to iterate the fire model.

Weighted Fuel Moistures

Rothermel (1972) introduced surface area weighting for calculation of rate

of spread. Weighting fuels by surface area results in a singular characteristic parameter for a fuel array composed of a mixture of particle sizes. Every fuel model has a fixed set of surface area weighting factors that are applied to the dead fuel moisture components (less than 1/4 inch, 1/4 to 1 inch, and 1 to 3 inches) and live fuel moistures (woody and herbaceous) to calculate the singular weighted fuel moisture for each fuel class. Table 3 illustrates these weighting factors for the 13 standard NFFL, or FBO fuel models. Except for the three slash models, the weight on the fine (1 hour) fuels is an order of magnitude greater than the 10 hour and 100 hour fuels for fuels with 10-h and 100-h fuels.

Table 3. Weighting factors for the 13 NFFL fuel models based on particle surface area to volume ratio.

		Dead Fuels			Live Fuels	
Model	Description	1	10	100	Herb	Woody
1	Short Grass (1 foot)	1.0	**	**	**	**
2	Timber (Grass and Understory)	.98	.02	**	1.0	**
3	Tall Grass (2.5 feet)	1.0	**	**	**	**
4	Chaparral (6 feet)	.95	.04	.01	**	1.0
5	Brush (2 foot)	.97	.03	**	**	1.0
6	Dormant Brush, Hardwood Slash	.89	.09	.02	**	**
7	Southern Rough	.89	.09	.02	**	1.0
8	Closed Timber Litter	.94	.03	.02	**	**
9	Hardwood Litter	.99	.01	**	**	**
10	Timber (Litter & Understory)	.94	.04	.02	**	1.0
11	Light Logging Slash	.77	.17	.06	**	**
12	Medium Logging Slash	.75	.19	.06	**	**
13	Heavy Logging Slash	.76	.18	.06	**	**

Solution of the fire behavior equations, requires both individual particle and weighted moistures. We made some assumptions about the relationships between the 1, 10, and 100 hour fuel moistures so we could take a single weighted moisture value and generate individual particle moistures for input

into the fire model. First we assumed a constant relationship between the 10 and 100 hour fuel moistures. They default to equality, but can be changed. The next assumption considers the relationship between the 1 hour and 10 hour fuel moistures and is more critical. From the surface area weighting concept in Rothermel (1972) we know that:

msw = wf1*ms1 + wf10*ms10 + wf100*ms100

where: msw is the weighted moisture content,

wf1, wf10, wf100 are weighting factors for 1, 10, and 100-h fuel, and ms1, ms10, and ms100 are the moisture contents of the dead fuels.

Since we've made the assumption that ms100 = ms10 + k

msw = wf1*ms1 + ms10*wf10 + wf100*(ms10 + k)

We then took the fine fuel moisture relationships used in the 1978 National Fire Danger Rating System (Fosberg and Deeming 1971):

ms1 = 1.03*EMC and

ms10 = 1.28*EMC, such that

ms10 = 1.2427*ms1

Substituting ms10 back into the equation above, and solving for ms1 (since we define our msw) we get

msw = wf1*ms1 + 1.2427*ms1*wf10 + wf100*(1.2427*ms1 + k)

msw = ms1*(wf1 + 1.2427*wf10+ 1.2427*wf100) + wf100*k

msw = ms1*(wf1 + 1.2427*(wf10+wf100)) + wf100*k

ms1 = (msw - wf100*k)/(wf1 + 1.2427*(wf10+wf100))

ms10 = 1.2427*ms1

ms100 = ms10 + k

which gives us the three component moistures for a given weighted fuel

moisture.

What we are saying is that a diversity of particle fuel moistures may combine to a unique weighted moisture value, but for any given weighted moisture value, we evaluate only a single set of particle moistures in the fire model; and, the solution set from the weighted moisture approach will be similar to that of evaluating many combinations of particle fuel moistures that yield the same weighted fuel moisture.

This assumption is quite valid for fuel models whose 1-hour weight is an order of magnitude more than the 10-h (NFFL models 1-10). For models with heavy 10- and 100-h fuel contributions, maximum differences of about 10 percent occur between the lowest and highest 10-h (and 100-h) moisture combinations at a single weighted fuel moisture level.

Live Fuel Moisture

We use the same concept in computing live fuel moisture components. Since there are only two components we assume the herbaceous moisture equals the woody fuel moisture for fuels that contain both types of live fuel. None of the standard NFFL models contain two classes of live fuels.

Fuel Models

The prototype version of WINDOW can use standard or custom fuel models, but currently does not support the two fuel model concept, or dynamic fuel models. Custom models should be developed using the FUELS section of the BEHAVE systems (Burgan and Rothermel 1984).

Program Operation

The proceedings paper provides a more complete overview of the system operation. The program currently resides in the 130 group account in the PERKIN ELMER 3220 at the Intermountain Fire Sciences Laboratory is Missoula. A CSS procedure, WINDOW.CSS begins the program. It operates on prompts and keywords and has a context sensitive help system. The keywords KEY, LOG, NOLOG, INPUT, LIST, CHANGE, RUN, TERSE, WORDY, PAUSE and NOPAUSE perform the same utility functions as in FIRE1 in BEHAVE. HELP in WINDOW is context sensitive and you may ask for help on a keyword (e.g. HELP WIND). In WINDOW, access to custom fuel files is automatic if 14 or greater is requested for a fuel model. Additionally a STATUS function gives current program status--module, fuel file name and log file name.

The keywords FIRE, WIND, and MOIST keywords control the function of the operational modules of WINDOW.

FIRE: Generates tables of prescribed burning windows given a fuel model, fuel exposure to the wind, and fire behavior constraints. Individual panes in the window illustrate relationship between wind and fuel moistures, which are further delineated in WIND and MOISTURE.

WIND: Generates tables of 20-foot wind speeds that result in unique effective midflame wind, given a fuel model, slope and exposure of fuel to wind. Tables are generated for head, flank and backing fires for winds that blow upslope, quarter upslope, cross slope, quarter down slope, and down slope.

MOIST: Generates tables that illustrate combinations of component fuel moistures for a given fuel model, that result in weighted fuel moistures.

When called from FIRE, WIND and MOIST use wind and moisture ranges identified in FIRE to generate tables. When called from WINDOW, the main program, WIND and MOIST accept user-defined wind and moisture ranges to generate tables.

Future Work

WINDOW is a prototype program; it is not ready to be given to the masses. We are beginning a testing phase with individuals involved in prescribed fire planning. We expect to have modifications in the user interface and output; perhaps users will require control some of the moisture assumptions we made. After testing, decisions will need to be make about the utility and future of WINDOW.

Should it become a kernel for networks of prescribed planning programs? Should it be made available on the HP-71B? Should additional models from BEHAVE be included so parameters such as maximum spotting distance can be combined with flame length in a prescription? Could we interface with a moisture model (Rothermel and others 1986) to generate weather (season, time of day, temperature, humidity, and precipitation) profiles and replace weighted moisture values? Could the mortality model developed by Reinhardt and Ryan (1986) integrate fire behavior and fire-effects single program? Will the program really be useful without incorporating the effects of pattern of ignition into the process?

My recommendations for work within the current program are:

1. Modify the program as suggested from the testing.
2. Document the effect of our assumptions on the accuracy of the fire behavior predictions for a range of fuel models and conditions.
3. Identify the scope and format of an implemented version of WINDOW.
4. Allow two fuel models and dynamic fuel models.

My recommendations for future expansions of the program are:

1. Investigate integrating the mortality model by Reinhardt and Ryan
2. Investigate interfacing with the Moisture model developed by Rothermel to make the final output in terms of weather profiles.

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APPENDIX A

A SYSTEM FOR DEFINING WINDOWS OF ACCEPTABLE BURNING CONDITIONS FOR PRESCRIBED FIRE BASED ON DESIRED FIRE BEHAVIOR

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1. INTRODUCTION

A computer program, WINDOW, has been developed as an aid for prescribed fire planning. It enables fire managers to obtain systematic and consistent answers to the question, "What wind and fuel moisture conditions do I need to conduct a prescribed fire with specific constraints on fire behavior?" Users specify ranges of desired fire behavior for a specific site with known fuels, and the program calculates the window of suitable environmental conditions. WINDOW reverses the mathematical fire spread model (Rothermel 1972, Albini 1976a) as it is implemented in the DIRECT module of the BEHAVE Fire Behavior Prediction and Fuel Modeling System (Andrews 1986). WINDOW employs all of the fire behavior information available in DIRECT including fire behavior prediction for custom fuel models; head, flanking, and backing fires; and variable wind direction.

The need for a program such as WINDOW is evidenced by the fact that many fire managers are using the BEHAVE system to establish windows for prescribed burn plans. Prior to the development of the program, we conducted a user needs survey of active prescribed burners. Two-thirds of those surveyed were using the BEHAVE system in various ways to define fire prescription windows. Two comments that often occurred regarding the need for a program such as WINDOW were "It would save a lot of BEHAVE runs" and "It would be helpful to identify more burning days." Perhaps Rod Norum (National Park Service) said it best: "The tools are currently available, but it becomes the agony of the chase to pull it together." Current fire behavior prediction tools, nomograms (Albini 1976b, Rothermel 1983), TI-59's (Burgan 1979), HP-71B's (Susott and Burgan 1986), and BEHAVE (Andrews 1986), are sufficient for simple prescribed fire scenarios (grass model, head fire, upslope wind) but quickly become cumbersome when cross-slope winds, nonhead fires, and complex fuel models are considered.

WINDOW is not the first program to provide summaries of prescribed burning opportunities based on desired fire behavior. BRNPLN (Hilbruner and Omi 1983, Hilbruner 1984) produces simple summaries of midflame wind speed and fuel moisture ranges with fire behavior predictions within constrained values. Although BRNPLN gives dimensions of the window, it does not provide information about the layout of the 'panes' within the window. For example, BRNPLN gives a window in the following form: midflame wind speed, 4 to 9 mi/h; 1-h fuel moisture, 5 to 12 percent. This implies that any combination of those values results in fire behavior within the prescription. In reality, combination of diagonal corner values (higher wind and lower moisture or lower wind and higher moisture) may or may not result in desired fire behavior. If all corner values are in prescription and the prescription is not constrained by a priori limits, then the system is not expanding windows to identify outlier combinations that could result in successful burns.

The ultimate goal of the WINDOW program is to generate windows of burning opportunities in a comprehensive fire prescription development system (Brown and Fischer 1986). A prototype version of such a system (Figure 1) is under development by the Fire Effects research work unit at the Intermountain Fire Sciences Laboratory in Missoula, Montana. It will integrate fire behavior and fire effects in an artificial intelligence (AI) format. In the meantime, WINDOW was designed as a stand-alone program, with users responsible for the interactions between fire behavior and fire effects for their prescribed fire plan. Examples of guidelines that are available for relating fire behavior to fire effects can be found in Gruell and others (1986) and Brown and Simmerman (1986). For different vegetation situations and prescription objectives, they outline various prescription considerations and parameters.

The WINDOW program is a small step toward the comprehensive system needed by prescribed fire planners. Cautions in the application of the fire spread model for prescribed fire are often repeated (Rothermel 1983, 1984, Brown 1984, Andrews 1986). The most overriding limitation is

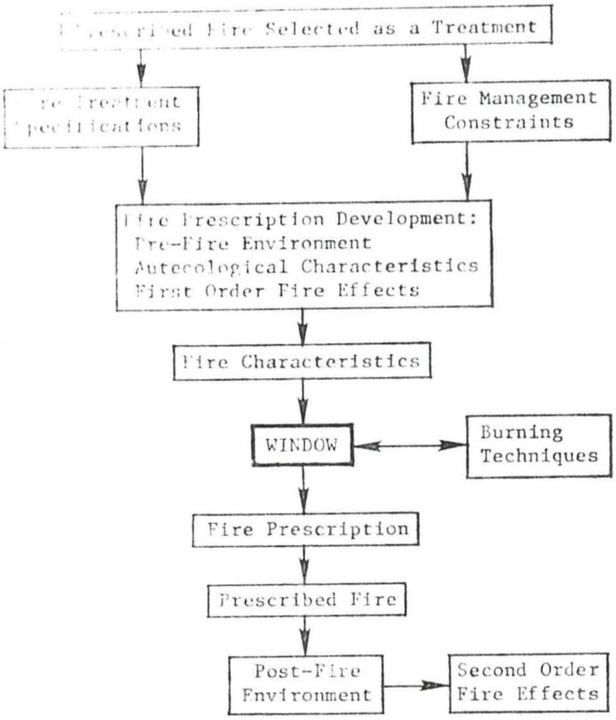

Fig. 1. Prescribed fire decision and development system adapted from Brown and Fischer (1986).

the fact that the model is based on the assumption that the behavior of the fire is no longer influenced by the method or pattern of ignition. With care, however, WINDOW can be used for some types of prescribed fire.

2. BASIS OF THE SYSTEM

The DIRECT module of BEHAVE requires up to 10 input values for the calculation of rate of spread and intensity. For a given prescribed fire, fuel model and slope are set and held constant. The challenge in designing WINDOW is then to describe combinations of the remaining eight input values that result in predictions of acceptable fire behavior.

The structure of the WINDOW program is based on the fact that the 10 input values required by the DIRECT module of BEHAVE are reduced to three intermediate values before the final fire model calculations are done. As diagrammed in Figure 2, fuel moistures for the three dead classes and two live classes are reduced to weighted moisture contents before the final calculations are done. Similarly, slope, wind speed, wind direction, and spread direction give an effective wind speed in the direction of spread. Fuel model is a factor in the calculation of both the weighted fuel moisture contents and the effective wind speed. Working with these intermediate values reduces 10 dimensions to a manageable three—weighted dead fuel moisture, weighted live fuel moisture, and effective wind speed at midflame height. WINDOW produces tables that give combinations of weighted fuel moistures and effective wind speed that result in predicted fire behavior within prescription limits. Weighted moisture contents are broken down into the moisture contents of the component parts. Effective wind speeds are displayed as a function of 20-foot wind speeds for various wind and spread directions.

The picture of 20-foot wind speeds, dead and live fuel moistures that WINDOW presents, lends itself nicely to computer systems that use climatic data from fire weather stations. For example, RXBURN (Bradshaw and Fischer 1981) identifies patterns and probability of occurrence of user defined prescribed fire-weather conditions.

3. PROGRAM DESIGN and APPLICATION

Designed for interactive use, program flow is controlled by keyword responses to prompts. To minimize the impact on users familiar with the BEHAVE system, the WINDOW user interface mimics that found in BEHAVE, and indeed, it has the same utility function keywords: TERSE, WORDY, PAUSE, NOPAUSE, LOG, NOLOG, KEY, and HELP. The keywords FIRE, MOISTURE, and WIND control the operational modules in WINDOW. The function of and interaction between these three modules is illustrated in Figure 3.

Table 1 summarizes the input values needed to use WINDOW. The general site description factors are required and are assumed constant for the fire. Fuel models may be the standard 13 or custom models developed in the fuel modeling section of BEHAVE (Burgan and Rothermel 1984). For fuel models with 100-h timelag fuels, WINDOW assumes a constant relationship between the 10-h and 100-h fuel moistures. Equality is the default, but users may change the relationship based on personal experience or analysis of local fire weather climatologies. One to six fire

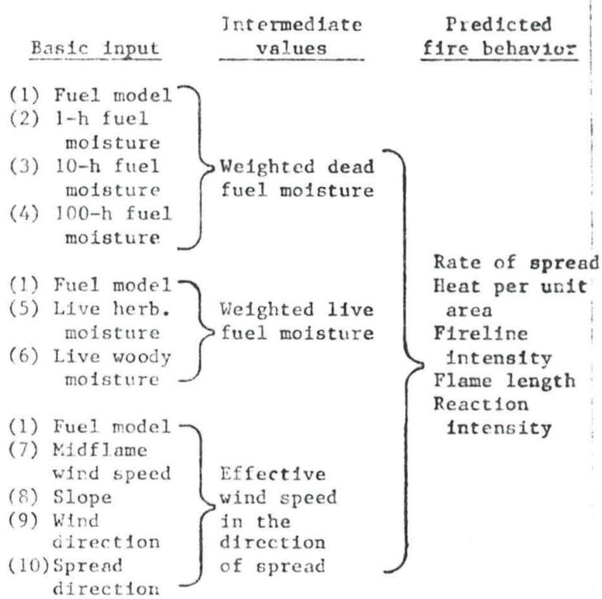

Fig. 2. The structure of the WINDOW program is based on the fact that the ten basic input values required by the DIRECT module of BEHAVE are reduced to three intermediate values before the final calculations are done.

[illegible] : Controls flow of program through prompts and keywords.

[illegible] : Generates tables of prescribed burning window, given a fuel model, fuel exposure to wind, and fire behavior constraints. Individual panes in the window illustrate relationship between wind speed and weighted fuel moistures, which may be further delineated in WIND and MOISTURE.

WIND : Generates tables of 20-foot wind speed that result in a unique effective midflame wind, given a fuel model, slope and exposure of fuel to wind. Tables are generated for head, flank and backing fires for winds that blow upslope, quarter upslope, cross-slope, quarter downslope, and downslope.

MOISTURE : Generates tables that illustrate combinations of component fuel moistures for a given fuel model, which results in unique weighted fuel moistures.

Interaction of WINDOW Modules

- WINDOW
  - FIRE
    - WIND
    - MOISTURE

    When called from FIRE, WIND and MOISTURE use wind and moisture ranges identified in FIRE to generate tables.
  - WIND
  - MOISTURE

  When called from WINDOW, WIND, and MOISTURE accept user-defined wind and moisture ranges to generate tables.

Fig. 3. Major components of the WINDOW program.

Table 1

Input values for the WINDOW program

Value	Notes
***** General Site Description *****	
Fuel Model	NFFL 1-13, or Custom.
Terrain Slope of Burn Area	
Exposure of Fuel to Wind	Exposed, partially sheltered, or fully Sheltered
Relationship of 100-h FM to 10-h Fuel Moisture	Program assumes constant relation between 10-h and 100-h Moisture
***** Fire Behavior Prescription *****	
Rate of Spread Flame Length Heat Per Unit Area Fireline Intensity Reaction Intensity	At least one must be selected
***** A Priori Environmental Limits *****	
1-h Fuel Moisture 10-h Fuel Moisture 100-h Fuel Moisture Live Woody Fuel Moisture Live Herbaceous Fuel Moist. Effective Windspeed	Optional

fire constraints may be used in a prescription. Optionally, for fire effects or fire control reasons, a priori constraints on fuel moistures and wind speed factors may be imposed.

We will use an example prescription scenario from Gruell and others (1986) to illustrate both the design and application of WINDOW. For a Douglas-fir seedling stage in a Douglas-fir/Idaho fescue habitat type and a resource objective to increase productivity of herbaceous vegetation and improve palatability, the fire objective is to kill 60 to 80 percent of the sagebrush and 60 to 80 percent or more of the Douglas-fir. A head fire with 2-foot or greater flame lengths is needed to kill the sagebrush and Douglas-fir seedlings. We will use NFFL fuel model 5, which generally applies to small brush where the fire is generally carried by litter and dead grass, especially at low wind speeds.

The following define the prescription input set for WINDOW:

Fuel Model	:	NFFL 5 (brush, 2 foot)
Slope	:	35 percent
Fuel Exposure to Wind	:	Exposed
Flame Length	:	2 feet or greater
Minimum Dead Fuel Moisture	:	5 percent
Maximum Effective Windspeed	:	10 mi/h at midflame height

1. FIRE Module

The FIRE module of the WINDOW program generates tables that display combinations of effective wind speed and weighted fuel moisture that result in predicted fire behavior within the constraints defined by the current input set. FIRE generates two types of tables: one for fuel models with only dead fuels, and one for fuel models with both dead and live fuels. Row values are effective wind speed, and column values are weighted dead moisture contents. "Panes" in the window (intersections of row and column values) with predicted fire behavior within prescription constraints are marked by "##" for models with only dead fuels. For fuel models that also contain live fuels, panes within prescription constraints contain prescription ranges of weighted live fuel moisture. Empty (blank) panes indicate that predicted fire behavior is outside the constraints for that particular wind and moisture combination.

Using the above inputs, a run of WINDOW's FIRE module generated the output displayed in Table 2. At the high dead fuel moisture range (16 percent) an effective midflame wind of at least 5 mi/h is required with maximum live fuel moisture of 50 percent. As effective wind increases to 10 mi/h, allowable live fuel moisture increases to 120 percent with a weighted dead moisture of 16 percent. At the low end of dead fuel moistures (5 percent) an effective wind speed of zero will suffice only if live fuel moisture is 50 percent or less. As live fuel moisture increases, higher effective winds are required with an final range of 30 to 300 percent for effective wind speeds of 7 mi/h or greater. At a constant effective wind, 4 mi/h for example, as weighted dead fuel moisture increases from 5 to 14 percent, maximum allowable live fuel moisture drops from 140 to 60 percent. Again, blank panes indicate out-of-prescription combinations of wind and moisture.

Table 2

Example table from the FIRE module of WINDOW.

Fuel Model	:	NFFL 5 (brush, 2 foot)
Exposure to Wind	:	Exposed
Fire Behavior	:	Flame length $\geq$ 2 feet
Constraints	:	Effective wind $\leq$ 10
		Dead Fuel Moisture $\geq$ 5

Effective wind speed and weighted fuel moisture combinations that result in fire behavior within prescription constraints.

Effect. wind (mi/h)	Weighted Dead Fuel Moisture, percent 5	6	8	10	12	14	16
0	30- 50	30- 40	30- 40	30- 30	30- 30		
1	30-110	30-100	30- 90	30- 70	30- 50	30- 30	
2	30-130	30-120	30- 90	30- 70	30- 50	30- 30	
3	30-130	30-120	30-100	30- 80	30- 60	30- 30	
4	30-140	30-120	30-100	30-100	30- 90	30- 60	
5	30-210	30-180	30-160	30-150	30-130	30-100	30- 50
6	30-280	30-250	30-210	30-200	30-180	30-150	30- 80
7	30-300	30-300	30-270	30-260	30-240	30-190	30-110
8	30-300	30-300	30-300	30-300	30-290	30-240	30-120
9	30-300	30-300	30-300	30-300	30-300	30-290	30-120
10	30-300	30-300	30-300	30-300	30-300	30-290	30-120

Ranges in cells are valid live fuel moistures (percent) that in combination with corresponding effective wind and weighted dead fuel moisture values are in prescription. Blank cells are out of prescription.

3.2 WIND Module

The effective wind speed displayed by FIRE, and used in fire behavior calculations, is the combined effect of slope, midflame direction, and fire spread direction. Midflame wind is related to 20-foot wind speed by a wind adjustment factor based on exposure of fuels to the wind. The 20-foot wind speed is often the basis for climatologies, prescribed burn plans, and spot weather forecasts.

WIND output is based on a constant slope. The table displays ranges of 20-foot wind speeds in five directions (with respect to slope) that correspond to a single effective wind speed. A table is generated for three types of fires: head, flanking, and backing. For each fire type, 20-foot wind speed ranges are computed for winds that blow upslope, quarter upslope, cross-slope, quarter downslope, and downslope. If the WIND module is invoked from within the FIRE module, effective wind speeds will coincide with those identified by the FIRE table. Alternatively, WIND may be invoked from outside of FIRE, allowing one to prepare a static set of tables (for a given fuel model and slope) for often-occurring prescription situations.

The 20-foot winds required for the example are summarized in Table 3. The first column contains the effective midflame wind speeds from Table 2. The next five columns define ranges of 20-foot winds that result in the corresponding effective wind speed in the direction of the head fire for the five wind directions on a 35 percent slope. Note that for upslope winds, 20-foot winds of 3 mi/h or less result in effective winds of 2 mi/h, while cross-slope and quarter upslope winds up to 5 mi/h also result in a 2 mi/h effective wind. Discontinuities in 20-foot wind speeds are a result of competition between the effects of slope and downslope wind. Downslope winds of 4 to 5 mi/h balance the slope effect, resulting in an effective wind of zero. Downslope 20-foot winds from 2 to 3 mi/h result in a head fire burning uphill; downslope 20-foot winds from 6 to 7 mi/h result in a head fire burning downhill. Both fires have effective wind speeds of 1 mi/h in the direction of spread of the head fire.

3.3 MOISTURE Module

The MOISTURE module displays combinations of moisture contents for the individual particle sizes that result in a given weighted moisture content. The moisture content of the 1-h fuels has a much greater effect on rate of spread predictions than does the moisture content of the 10-h and 100-h fuels. Weighting factors for each size class are given with each MOISTURE table.

Like the WIND module, MOISTURE may be invoked from FIRE to display only the range of weighted moistures defined by FIRE, or it may be used independently to build static tables of weighted fuel moistures for a given fuel model. Two tables are built by MOISTURE: one for dead fuel moisture and one for live. Row values are weighted fuel moistures and coincide with weighted moistures displayed in a FIRE table. In the dead moisture table, column values are 1-h fuel moistures, and table values are ranges of 10-h that combine with the column 1-h value to generate the weighted dead fuel moisture contents for the row. Blank cells indicate that no combinations yield the row value. Live moisture tables for custom fuel models with two classes of live fuel employ the same concept. The column value is the herbaceous moisture content, and the table value is the range of woody fuel moisture that results in the weighted live fuel moisture (row) value.

Table 3

Example table from the WIND module of WINDOW.

Fuel Model : NFFL 5 (brush, 2 foot)
Exposure to Wind : Exposed
Wind Adjustment Factor : 0.4
Slope : 35 percent
Fire Type : Head Fire

Ranges of 20-foot winds (mi/h) that give effective wind at midflame height.

Effective Windspeed (mi/h)	================ Wind Direction================				
	Upslope	Qtr-Up	X-Slope	Qtr-Down	Downslope
0					4-5
1				2-5	2-3,6-7
2	0-3	0-5	0-5	0-1,6-7	0-1,8-9
3	4-7	6-7	6-9	8-9	10-11
4	8-9	8-9	10-11	10-13	12-13
5	10-13	10-13	12-13	14-15	14-15
6	14-15	14-15	14-17	16-17	16-17
7	16-17	16-17	18-19	18-19	18-21
8	18-19	18-19	20-21	20-23	22-23
9	20-23	20-23	22-23	24-25	24-26
10	24-25	24-25	24-26	26-28	27-29

Midflame wind = wind adjustment factor x 20-foot wind

Table 4 illustrates the breakdown of weighted dead fuel moistures for fuel model 5. Note that 97 percent of the weight is on the 1-h fuel and that the model contains no 100-h fuels. The 1-h fuels dominate the weighted dead fuel moisture computation, and for this example, 10-h moisture is insignificant. Interpretation of Table 4 is straightforward: the weighted moisture (row value) always equals the 1-h value, no matter the 10-h moisture value. Compare Table 4 for fuel model 5 to Table 5 for fuel model 13. Both tables give combinations of individual moisture contents that result in weighted dead fuel moisture contents from 5 to 16 percent. For fuel model 13, 75 percent of the weight is on 1-h, 19 percent on 10-h, and 6 percent on 100-h. As a result, there are several possible particle fuel moisture combinations for each weighted dead fuel moisture value.

4. FUTURE WORK

The next step in connection with WINDOW depends on the results of field tests of the prototype. If it proves useful in its present form, we will add it to the BEHAVE system with the approval of the USDA Forest Service's Washington Office, Fire and Aviation Management.

Table 4

Example table from MOISTURE for NFFL model 5.

Fuel Model : NFFL 5 (brush, 2 foot)

Moisture Weighting Factors : 1-h = 97.3 percent
: 10-h = 2.7 percent

Ranges of 10-h fuel moistures (percent) that give weighted fuel moisture at a given 1-h fuel moisture value.

Weighted moisture, percent	1-h Fuel Moisture, percent: 5	6	7	8	9	10	11	12	13	14	15	16
5	1-30											
6		1-30										
7			1-30									
8				1-30								
9					1-30							
10						1-30						
11							1-30					
12								1-30				
13									1-30			
14										1-30		
15											1-30	
16												1-30

Table 5

Example table from MOISTURE for NFFL model 13.

Fuel Model : NFFL 13 (heavy logging slash)
Relation of 100-h to 10-h : 100-h = 10-h + 3 percent
Moisture Weighting Factors : 1-h = 74.8 percent
: 10-h = 19.0 percent
: 100-h = 6.2 percent

Ranges of 10-h fuel moistures (percent) that give weighted fuel moisture at a given 1-h fuel moisture value.

Weighted moisture, percent	1-h Fuel Moisture, percent: 5	6	7	8	9	10	11	12	13	14	15	16
5	6- 3											
6	10- 7	6- 3	4- 3									
7	14-11	10- 7	8- 5	4- 3								
8	18-15	14-11	12- 9	8- 5	6- 3							
9	22-19	18-15	16-13	12- 9	10- 7	6- 3	4- 3					
10	24-23	22-19	20-17	16-13	14-11	10- 7	8- 5	4- 3				
11		24-23	24-21	20-17	18-15	14-11	12- 9	8- 5	6- 3			
12				24-21	22-19	18-15	16-13	12- 9	10- 7	6- 3		
13					24-23	22-19	20-17	16-13	14-11	10- 7	6- 3	4- 3
14						24-23	24-21	20-17	18-15	14-11	10- 7	6- 5
15								24-21	22-19	18-15	14-11	10- 7
16									24-23	22-19	18-15	14-11

We will write a users manual describing operation and appropriate application with emphasis on limitations.

The form of the output may be modified and expanded based upon input from the field test. It would be interesting to present the results graphically, possibly in the form of nomograms or fire characteristics charts (Andrews and Rothermel 1982).

Additional prediction models from BEHAVE might be included in WINDOW. The fine dead fuel moisture model could be used to make the connection to temperature and relative humidity for various times of day. The contingency plan part of the prescription could use predictions for maximum spotting distance, size of a spot fire after a given length of time, and the suppression forces required to contain the spot at a specified size. The behavior of an escaped fire would meet the assumption of steady state fire spread.

A mortality model developed by Reinhardt and Ryan (1986) could be the next logical step for WINDOW, as it makes a connection between fire behavior and fire effects. The model gives maximum allowable flame length for a given level of mortality using tree species, diameter, and height and crown ratio.

5. SUMMARY

WINDOW is a computer program that reverses the computational processes in the DIRECT module of the BEHAVE Fire Behavior Prediction and Fuel Modeling System. It is designed as a prescribed fire planning aid. Fire managers can get detailed windows of required fuel moisture and wind conditions based on desired fire behavior. They can then use other planning programs such as BRNPLN to identify the probability and patterns of occurrence of various panes of the window from local fire weather climatologies. Because the program design of WINDOW is similar to BEHAVE, which many potential users are familiar with, the program could be easily assimilated into the user community.

WINDOW is still in the early stages of development. The prototype is being tested and is subject to revisions and expansions. Ultimately, the logic in WINDOW may be used for defining burning conditions in a comprehensive prescription development system that links fire effects to fire behavior.

6. ACKNOWLEDGEMENT

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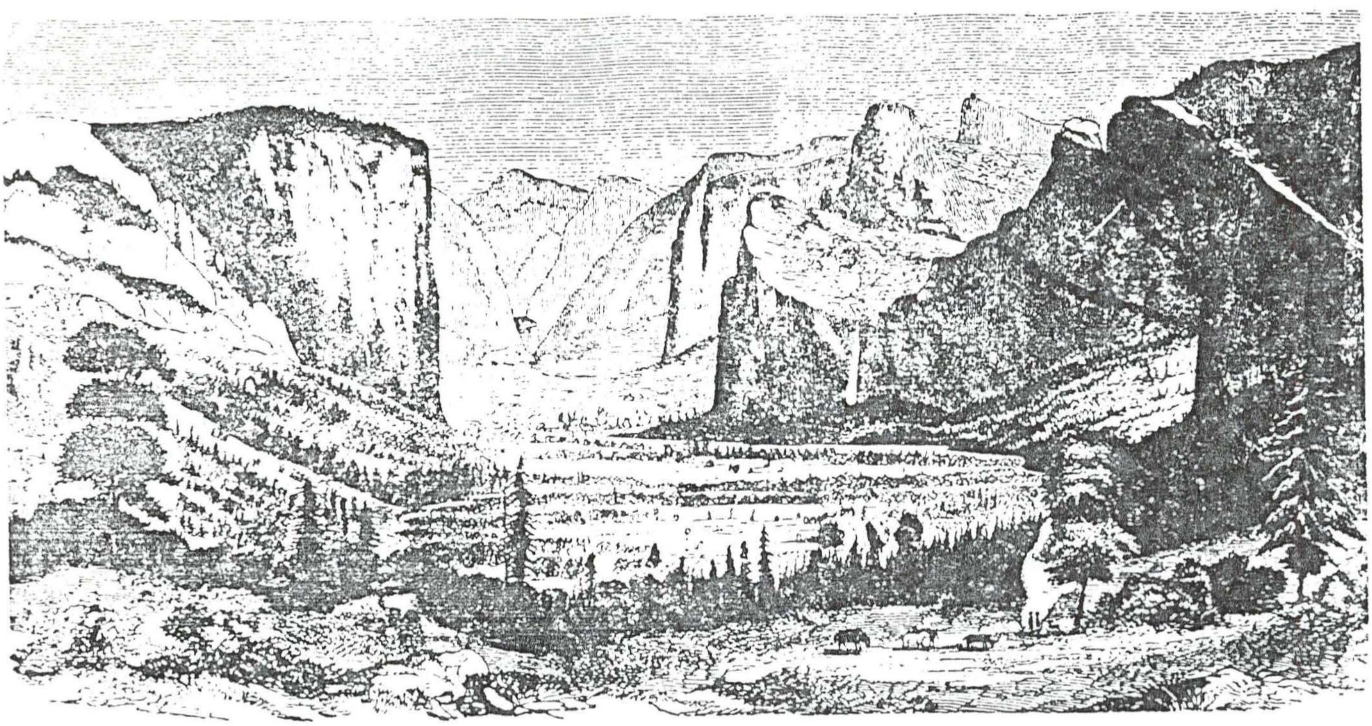
APPENDIX B

Prescribed Fire Planning

User Needs Survey

August 1986



U.S.D.A. Forest Service
Intermountain Fire Sciences Laboratory
Fire Behavior Research

Systems for
Environmental Management
Missoula, Montana

WINDOW User Profile and Needs Survey

Name: ______________________ Position: ______________________

Address: ____

1. Whom do you represent in responding to this survey? (e.g. self, District, Forest, National Park, etc.)?

____

2. About how many acres do you burn each year?

X 20,000 acres/yr SD= 71,000 MODE= 5,000 acres

QUARTILES= 2,000 5,000 10,000

3. About how many prescribed fires do you conduct fires each year?

15 fires/yr MODE= 30

QUARTILES 6 15 60

4. About how many hours do you and your staff spend developing prescriptions for a typical prescribed fire?

X 21 hours SD= 29 MODE= 2 hours

QUARTILES: 4 9 21

5. On what parameters do you usually base your prescriptions? (Check all that apply).

- [ ] Wind Speed
- [ ] Temperature
- [ ] Stick Moisture
- [ ] Sky Cover
- [ ] Time of Day
- [ ] ______________
- [ ] ______________

- 78 [ ] Wind Direction
- 85 [ ] Relative Humidity
- 84 [ ] Fine Fuel Moisture
- 67 [ ] Season
- 36 [ ] Fire Danger Indices
- [ ] ______________
- [ ] ______________

6. What aspects of fire behavior do you consider in writing prescriptions? (Check all that apply).

- [ ] Smoke Production
- [ ] Spread Rate
- [ ] Scorch Height
- [ ] Heat Release Rates
- [ ] Burn Objectives
- [ ] ______________
- [ ] ______________

- 82 [ ] Flame Length
- 66 [ ] Spotting Potential
- 40 [ ] Resistance to Control
- 38 [ ] Escaped Fire Contingency
- 16 [ ] Large Fuel Reduction
- [ ] ______________
- [ ] ______________

7. To what extent do you use ignition pattern to manipulate fire behavior?

- [ ] All the time
- [ ] Most of the time
- [ ] Some of the time
- [ ] Rarely or never

missing

Please Explain: SEE LIST

____

____

8. Which ignition methods and ignition patterns do you usually employ?

- 13 [ ] Hand Held Drip Torches
- [ ] Helitorch
- [ ] Flares/Fusees
- 11 [ ] Ping-Pong Balls
- 18 [ ] Propane Torch
- [ ] MATCHES +
- [ ] [illegible] TORCH

- 80 [ ] Strip Head Fire
- 71 [ ] Strip Backing Fire
- 35 [ ] Spot Fire (Head or Back)
- 38 [ ] Center/Ring Fire
- 44 [ ] Flank Fire
- 7 [ ] Chevron + Single
- [ ] Spot

9. Roughly what percent of your unit's fires are for:

Fuel Reduction/Slash Disposal	33 %
Wildlife Habitat Improvement	28 %
Vegetation Management	28 %
Site Preparation	15 %
Other ____________	1 %
Other ____________	____ %

10. Please check your perceived importance of these parameters while developing a burning prescription.

	Not Imp.	Slightly Imp.	Mod. Imp.	Very Imp.	Missing
Desired Fire Behavior	---	---	14.5	83.6	1.8
Pattern of Ignition	3.6	7.3	41.8	47.3	---
Method of Ignition	10.9	29.1	32.7	27.3	---
Escaped Fire Potential	---	14.5	25.5	58.2	1.8
Spotting Potential	1.8	18.2	36.4	43.6	---
Personal Experience	1.8	5.5	23.6	69.1	---
Fuel Inventory	12.7	27.3	45.5	14.5	---
Prescription Objectives	---	---	18.2	80.0	1.8
Fuel Moistures	---	---	30.9	67.3	1.8
Smoke Production	3.6	18.2	47.3	29.1	1.8
Other ____________					
Other ____________					
Other ____________		[ ]	[ ]	[ ]	[ ]

11. Which of the following do you use for the fire behavior aspects of prescribed fire planning?

- [ ] Personal Experience
- [ ] Nomograms
- [ ] Local Guidelines (Tables, Notebooks)
- [ ] TI-59
- [ ] HP-71B
- [ ] BEHAVE
- [ ] NFDRS
- [ ] Other ____________
- [ ] Other ____________

12. Please briefly describe how you use them. ______________________________

13. Do you feel these methods are sufficient for developing burning prescriptions?

67 % YES

33 % No

14. What has been your exposure to these programs or databases?

(Sometimes: 1-3 times/year)
(Often : 4 or more/year)

	Never Heard Of	Know. Don't Use	Use Some-times	Use Of-ten	Miss-ing
FIREFAMILY (FIRDAT)	1.8	29.1	45.5	14.5	9.1
AFFIRMS	---	16.4	25.5	57.4	1.8
NFDRS	---	12.7	20.0	63.6	3.6
RXBURN	10.9	40.0	32.7	5.5	10.9
RXWTHR	10.9	40.0	32.7	5.5	10.9
PRESCRIB	38.2	32.7	7.3	7.3	14.5
BRNPLAN	60.0	23.6	1.8	1.8	12.7
RXFIRES	47.3	34.5	6.3	---	12.7
NFWDL (Nat'l Fire Weather Data Library)	12.7	32.7	34.5	10.9	9.1
NFODL (Nat'l Fire Occurrence Data Library)	18.2	40.0	23.6	7.3	10.9
HAZARD	36.4	29.1	20.0	1.8	12.7
DEBMOD	38.2	29.1	18.2	1.8	12.7
QDEBRIS	52.7	21.8	9.1	1.8	14.5
BEHAVE	----	18.2	25.5	52.7	3.6
NEWMDL	16.4	23.6	36.4	18.2	5.5
TSTMDL	25.5	16.4	34.5	16.4	7.3
FIRE1	25.5	9.1	20.0	38.2	7.3
FWIS	47.3	30.9	5.5	3.6	12.7
WOODY II	68.8	20.8	10.4	----	12.7
BIOMASS	79.2	16.7	2.1	2.1	12.7
SAGE	72.7	12.7	2.0	2.0	10.9
PCBEHAVE	38.2	30.9	9.1	10.9	10.9
FIRECAST	43.6	30.9	5.5	5.5	14.5
______________	[ ]	[ ]	[ ]	[ ]	

15. Do you have access to these computers?

	No	Yes	Not Sure	MISSING
USDA, FS Data General Systems	35 [ ]	49 [ ]	6 [ ]	11
USDA, FS UNIVAC at Ft. Collins	24 [ ]	67 [ ]	2 [ ]	7
Shared Access to Minicomputer	20 [ ]	55 [ ]	11 [ ]	15
Shared Access to Mainframe	27 [ ]	42 [ ]	11 [ ]	20
Microcomputer (desktop)	11 [ ]	75 [ ]	7 [ ]	7

If micros, what kind(s) ______________________

16. Do you feel current levels of fire-effects knowledge are adequate for developing a system that uses fire behavior-fire effects relationships as a primary input?

No - 67%

Yes - 33%

17. Do you feel current fire behavior prediction techniques are adequate for prescribed fire planning?

No - 53%

Yes - 47%

18. Do you feel there is a need for a system such as WINDOW?

[ ] Yes, a great need
[ ] Yes, some need
[ ] No
[ ] Not sure

Please explain: SEE LIST

19. What type of personnel would use it? (FMO's, summer help, etc.)

____

20. What format(s) would you most like to use: (check all that apply)

[ ] Nomograms
[ ] Notebooks with tables
[ ] Handheld Calculator
[ ] Terminal Access to a remote system (e.g. FCCC)
[ ] Terminal Access to local Minicomputer
[ ] Forest Service Data General System
[ ] Microcomputer (desktop)
[ ] Other [illegible]
[ ] Other ______________________

21. Would you like to see WINDOW as a BEHAVE subsystem or an independent program?

[ ] BEHAVE Subsystem
[ ] Independent Program

22. Could WINDOW combine or replace programs you currently use, or would it be an additional program?

[ ] In Addition
[ ] Replace

23. Please check your perceived usefulness of information WINDOW could provide for your burn plans: (PERCENT)

	Not Useful	Slightly Useful	Mod. Useful	Very Useful	MISSING
Window of wind speed, direction, and fuel moisture conditions.	2 [ ]	0 [ ]	16 [ ]	78 [ ]	4
Above window with translation into temperature, humidity, and precipitation profiles.	2 [ ]	2 [ ]	31 [ ]	60 [ ]	5
Window conditions linked to local climate summary to provide seasonal scheduling profiles of windows.	9 [ ]	7 [ ]	26 [ ]	53 [ ]	5
Prescriptions with spotting and probability of ignition constraints.	2 [ ]	24 [ ]	27 [ ]	44 [ ]	4
Other ______________________	[ ]	[ ]	[ ]	[ ]	
Other ______________________	[ ]	[ ]	[ ]	[ ]	

24. What would be the most useful form of output from WINDOW?

____

____

____

____

____

____

____

____

25. How many years of fire supression experience do you have?

$\bar{x}$ = 18 ______ years SD = 7 MODE = 18.

QUARTILES ; 12 18 24

26. How many years of prescribed fire experience do you have?

$\bar{x}$ = 13 ______ years SD = 6 MODE = 10

QUARTILES: 10 11 16

27. About how many fire related workshops, courses, or training sessions have you attended since 1980?

MEAN = 10 ______ sessions MODE = 10

QUARTILES : 5 10 14

28. Did any of these include training on computer programs?

37 [ ] Yes
13 [ ] No

29. What would be the most effective way to learn WINDOW?

[ ] Workbooks and Self Instruction
[ ] Local Workshops or Training Sessions
[ ] Regional Workshops or Training Sessions
[ ] National Training Courses
[ ] Other ______________________________

30. Over your career, which fire related training events have been most useful to you?

____

____

31. Would you consider testing a prototype of WINDOW?

78 [ ] Yes, I would like to
16 [ ] I will if requested
0 [ ] No, I'm not interested
6 - UNANSWERED

32. If there is anything you, as a prescribed fire planner and/or burner could get out of a new computer system, what would it be? No limits, anything you want.

____

____

____

____

____

____

THANK YOU FOR YOUR TIME AND CONSIDERATIONS

List of Survey Recipients July 30, 1986

Name	Position	Unit
Agency : USDI, BIA		
Jim Roessler	Fire Management	BIA - Alaska
n Hartzell	Fire Management	BIA - Arizona
Mike Wallace	Fire Management	BIA - Wash. State
Agency :USDI, BLM		
Michael Penfold	State Director	BLM - ALASKA
Dean Bibles	State Director	BLM - ARIZONA
Jack Wilson	BLM Coordinator	BLM - BIFC
Ed Hastey	State Director	BLM - CALIFORNIA
Kannon Richards	State Director	BLM - COLORADO
Delmar Vail	State Director	BLM - IDAHO
Dean Stepanek	State Director	BLM - MONTANA
Edward Spang	State Director	BLM - NEVADA
Charles Luscher	State Director	BLM - NEW MEXICO
William Leavell	State Director	BLM - OREGON
Gardner Ferry	Fire Ecology	BLM - Oregon State Office
Roland Robison	State Director	BLM - UTAH
Phil Range	BLM - Aviation & Fire Mgmt	BLM - WO
Hillary Oden	State Director	BLM - WYOMING
Agency : USDA, FS		
Region: R-1		
Jerry Williams	Fire & Fuels Mgmt	Lolo National Forest
Wally Huff	Fire Management	Idaho Panhandle N.F.
Dave Thomas	Fire Management	Powell R.D. Clearwater N.F
Dave Bunnell	Wildlife, Fish, & Fire Mgmt.	Flathead National Forest
Gary Meyer	Fire Management	Clearwater National Forest
George Curtis	Fire Mgmt Officer	Kootenai NF, Eureka R.D.
Walt Tomascak	Fuels Management	Region 1
David Sisk	Fire Mangement	Seely Lake RD, Lolo NF
Region: R-2		
Dick Harrington	Fire Management	Forestry Sciences Laboratory
Al Roberts	Fuels Management,	USDA-FS, Regional Office
Bob Kenney	Fire/Fuels Mgmt.	Grand Mesa-Uncomp. N.F.
Phil Anderson	Fire/Fuels Mgmt.	Rio Grande N.F.
Al Braddock	Fire/Fuels Mgmt.	Black Hill N.F. -SO
* Region: R-3		
Stephen Servis	Fire Management	Gila National Forest
H. Dewayne Morgan	Fire Management	Prescott National Forest
William Russell	Fuels Management,	USDA-FS, Regional Office

Name	Position	Unit
* Region: R-4		
William Price	Fire Staff	Ashely National Forest
Jim Brown	Fire Effects Project Leader	Intermountain Fire Sciences Lab
Bill Fischer	Research Forester	Intermounain Fire Sciences Lab
George Gruell	Fuels Management,	USDA-FS, Regional Office
John Chapman	Fire Management	Bridger Teton National Forest
Gene Benedict	Fire Management	Payette National Forest
* Region: R-5		
Thom Myall	Fire Management	Los Padres National Forest
Robert Bryant	Fire Management	Klamath National Forest
Gerald Jensen	Fire Management	Modac National Forest
John Hatcher	Fire Management	San Bernadino National Forest
Jack Cohen	Prescribed Fire	Riverside Fire Laboratory
Dick Harrell	Fuels Management,	USDA-FS, Regional Office
Gary Biehl	Fire/Fuels Mgmt.	Covelo R.D., Mendocino N.F.
* Region: R-6		
Stan Kunzman	Fire Management	Deschutes National Forest
Jerry Brown	Fire Management	Gifford-Pinchot National Forest
Gordie Schmidt	Aviation & Fire Management	Mt. Hood National Forest
Don Carlton	Fuels Management	Mt. Hood National Forest
Jim Elms	Fuels Management,	USDA-FS, Regional Office
* Region: R-8		
Jim Lunsford	Fuels Management,	USDA-FS, Regional Office
Larry Ford	Fire/Fuels Mgmt.	USFS - Forida
Malcolm Jowers	District Ranger	USFS - Georgia
Lynn Marsalis	Fire/Fuels Mgmt.	USFS - Mississippi
Jack Kriesel	USFS - Arkasas	Forest Service Office
Ron Coats	Fire/Fuels Mgmt.	Pine Knot Job Corp (KY)
Clint Sykes	Fire/Fuel Mgmt.	National Forest of Texas
* Region: R-9		
Robert Willis	Fire Management	Mark Twain National Forest
Ed Kautz	Fuels Management	USDA-FS, Region 9
Jim Burdick	Fire Management	Superior National Forest
* Region: R-10		
Dennis Pendleton	Fire Management,	Cooperative & NFS Fire Mgmt
* Region: WO		
Roger Eubanks	Fuels Management	Washington Office
** Agency : USDI, FWS		
Calvin Gale	Fire Management	Fish & Wildlife Service (MN)
Ray Ferinetti	Fire Management	Merritt Island NWR (FL)
Frank Cole	Fire Mangement,	BIFC - USFWS
Merideth Weltner	Fire Management	Wichita Mtns NWR (OK)

Name	Position	Unit
** Agency : USDI, NPS		
Brad Cella	Fire Mgmt.	Wrangell St. Elias Natl. Park
Rod Norum	NPS Coordinator	NPS - BIFC
Jan vanWagtendonk	Fire Specialist	Yosemite National Park
Bob Doren	Fire/Fuels Mgmt.	Everglades National Park
Bruce Freet	Fire Management	Big Cypress Natural Preserve
Paul Broyles	Fire Management	Wind Caves Natl. Park (SD)
David McHugh	Fire Management	Big Thicket Natl. Preserve
Dean Clark	Fire Mgmt - Whiskeytown Unit	Whiskytown-Shasta-Trinity Rec. Area
Tom Gavin	Fire Management	Natl. Park Service-Western Reg
** Agency : PRIVATE		
Mark Heitlinger	Land Steward	The Nature Conservancy
Charles Bushey	Fire Specialist	Montana Prescribed Fire Service
** Agency : STATE		
John See	Asst. Reg. For. - Fire Mgmt	AK DNR, Div. of Forstry
Wayne Mitchell	Fire Management	Californa Department of Forestry
Charles Maynard	Fire/Fuels Mgmt.	Florida Div. of Forestry
John Crumb	Fire & Fuels Mgmt.	Dept. of State Lands
Scott Heather	Fire Management	Michigan DNR
George Meadows	Fire/Fuels Mgmt.	Minnesota DNR
Ed Matthews	Fire Management	Dept. of State Lands
John Shepherd	Fire/Fuels Mgmt.	North Carolina DNR
Hugh Ryan	Fire/Fuels Mgmt.	South Carolina Foresty Comm.
Gary Cornell	Fire/Fuels Mgmt.	Utah State Lands and Forestry
Greg Ariss	Fire/Fuels Mgmt.	Washington State DNR
Duane Dupor	Fire/Fuels Mgmt.	Wisconsin DNR
** Agency : UNIVERSITY		
Bob Martin	Professor	UC-Berkeley, Dept For & Res Mgmt
Phil Omi	Professor	CSU, Dept For & Wood Science
Leon Neuenshwander	Professor	UI, Dept. of Forest Resources
Ron Wakimoto	Professor	UM, Dept. of Forestry
Lester Holley	Professor	N. C. State, Dept of Forestry
Stew Pickford	Professor	WU, Dept of Forest Sciences
Benjamin Zamora	Professor	WSU, Dept For & Range Mgmt
Andi Koonce	Associate Prof.	U. Wisc., College Natural Res.

United States Department of Agriculture | Forest Service | Intermountain Research Station | Fire Sciences Laboratory
P.O. Box 8089
Missoula, MT 59807

Reply to: 4400 Forest Fire Research

July 30, 1986

Subject : Prescribed Fire Planning

David Sisk
Fire Mangement
Seely Lake RD, Lolo NF
Seely Lake, MT

Dear David:

We are soliciting ideas from fire managers concerning a computer system that will be an aid to prescribed fire planning. Please take about 15 minutes to complete and return the enclosed survey. If you feel someone on your staff would be more appropriate, please pass it on to him or her. We would like to have a response by August 20.

We are just beginning work on a program called WINDOW that will reverse the calculations in the BEHAVE fire behavior prediction system. The fire manager will specify desired fire behavior for a specific site and the system will calculate a window of suitable environmental conditions (fuel moistures, wind speed and direction). The ultimate goal is for this program to be the fire behavior module in a comprehensive fire prescription development system. In the meantime, it will be a stand-alone system, with the user being responsible for the connections to fire effects. The first step will utilize only the prediction models in BEHAVE. Future expansions will include other fire behavior prediction models, fire effects relationships, and a link to historical weather information.

We are interested in your perceptions on the utility of WINDOW, features you would want in it, and the media you'd prefer to use. There are also some questions about computer programs you may use, in-service training that you have had, and your feelings about the adequacy of current fire effects and fire behavior prediction models for prescribed fire planning. Additional comments that don't fit into the blanks on the form are welcome.

In addition, we would appreciate it if you would send us a copy of the form that you use in your burn plans and/or an example burn plan.

Thank you for your time; we hope to hear from you within two weeks. If you have any questions, please call.

Patricia L. Andrews
Fire Behavior Research
Intermountain Fire Science Lab
406-329-4827
FTS 584-4827

Larry S. Bradshaw
Research Meteorologist
Systems for Environmental Management
406-549-7478

LIST OF 'OTHER' WRITTEN IN PARAMETER ON PRESCRIBED BURNING NEEDS SURVEY

OTHER PRESCRIPTION PARAMETERS:

AGENCY	NAME	RX_1_WHAT	RX_2_WHAT
BLM	Bob Clark	Smoke	All FM's
BLM	Bob Raper	Soil Moisture	Live Fuel Moist
BLM	Bill Casey	10 hour fm	
BLM	Greg Zschaechner	Live Fuel Moist	
FS	Bill Fischer	Fuel Complex	Measured FM
FS	Dave Thomas	1000 hr fm	
FS	Jim Webb		duff moist
FS	Jack Kriesl	Mixing Hght	CSI
FS	Al Braddock	slope	Live FM
NPS	Robert F. Doren	Water Level	1000 HR FM
NPS	DAVID McHUGH	FUEL MODEL	MANPOWER
PRIV	Chuck Bushey		Soil Moisture
STATE	Scott Heather		1972 NFDRS
STATE	JOHN CRUMB	FUEL MODEL	
UNIV	Leon Newenshwander		duff moisture

?

OTHER FIRE BEHAVIOR PARAMETERS:

AGENCY	NAME	FB_1_WHAT	FB_2_WHAT
BLM	Bill Casey		Smoke Direction
FS	Al Braddock	Tree Mortality	
FWS	Frank Cole		Personnel Req.
STATE	JOHN CRUMB	DUFF REDUCTION	SMOKE DIRECT

?

OTHER IGNITION METHODS:

AGENCY	NAME	METH_1_WHA
BIA	Ralan Hartzell	Matches
BLM	Bob Clark	Terra torch
BLM	Bob Raper	Terra Torch
BLM	Mike Fisher	Terra Torch
BLM	Carl St. Clair	Terra Torch
BLM	Larry Taylor	Terra Torch
BLM	Greg Zschaechner	Terra Torch
FS	Wallace Huff	
FWS	Calvin Gale	Matches
NPS	Robert F. Doren	DAIDS

?

OTHER IGNITION PATTERNS:

AGENCY	NAME	PATT_1_WHA
FS	Dave Bunnell	Chevrons
FS	Ron Coats	backing
NPS	Robert F. Doren	Single Ignition
STATE	Wayne Mitchell	Scatter

?

OTHER PARAMETERS OF IMPORTANCE RATING:

AGENCY	NAME	IMP_1_WHAT	IMP_2_WHAT
BIA	Jim Roessler	Fuel Model	
BLM	Bob Raper	Residual Intens, soil moisture	
BLM	Bill Casey	smoke direction, leave areas	
BLM	Larry Taylor	Costs	
FS	Jim Lundsford	Wind Direction	
FS	Wallace Huff	Safety	mop-up costs
NPS	Robert F. Doren	Temperature	1000 HR FM
NPS	DAVID McHUGH	AVAIL. WINDOW	SIZE OF AREA
UNIV	Leon Newenshwander	fuel load/continuity	

?

OTHER TOOLS/PROGRAMS USED:

AGENCY	NAME	USE_1_WHAT	USE_2_WHAT
BLM	Bill Casey	Historical Data	
BLM	Carl St. Clair	Burning AZ Oak	
FS	Bill Fischer	Fuel/Duff Reduc	
FS	Dave Bunnell	DEBMOD, QBERIS, HAZARD, DWI	
FS	Fritz Cahill	FIRECAST	
FWS	Calvin Gale	Past Burn Docs.	
FWS	Ward Feurt	pc\behave	
NPS	Robert F. Doren	scorch maps	
PRIV	Mark Heitlinger	pcbehave	
STATE	Wayne Mitchell	FIRECAST	
STATE	Scott Heather	1972 NFDRS	

?

OTHER FORMATS DESIRED:

AGENCY	NAME	FMT_1_WHAT
BLM	Mike Fisher	IAMS
BLM	Philip Parks	IAMS

?

OTHER VALUES IN IMPORTANCE RATING:

AGENCY	NAME	IMP_21_WHA
FS	Bill Fischer	ditto + time of
FS	Dave Bunnell	Green Fuel
FS	Jim Webb	flame length
FS	Al Braddock	Veg. Conditions
NPS	Robert F. Doren	Fire Effects
NPS	WILLIAM B CELLA	SCORCH HTS

Comments On Use of Firing Patterns

Broken Out By Agency

Respondent's Name	1=Always 2=Mostly 3=Sometimes 4=Rarely	Remarks
** Administrative Agency : BIA		
Jim Roessler	3	Only when necessary.
Ralan Hartzell	3	Depends on weather and prescription parameters.
** Administrative Agency : BLM		
Larry Taylor	3	When burn is not meeting prescription objectives
Bob Clark	2	On Slash Units use pattern to control FL, INT to prevent escape. On rangelands use pattern to minimize costs & time. Especially important in discontinuous fuel.
Mike Fisher	2	Strip head fire most common method.
Bill Casey	1	Ignition pattern varies in accordance with objectives, wind, slope, conditions (weather), time of day, etc.
Melanie Miller	0	It would be nice to able to predict the behavior of fires manipulated by ignition pattern.
Greg Zschaechner	2	No Comment
Philip Parks	1	Either strip head fires or head fire.
Rob Raper	1	By setting a wide window and relying on ignition pattern to regulate how intense we want the fire to get. This allows for a large choice to exist for different situations.
Carl St. Clair	2	Use ignition pattern to assist in control and intensity of burn.
Walt Schopfer	2	No Comment
Phil Range	1	No comment
** Administrative Agency : FS		
R. Lynn Marsalis	2	To control intensity. Head Fire for more, back fire for less
Jim Webb	1	Utilizing ignition pattern will allow us to burn under a much wider RX.
Dave Thomas	1	This is what makes the fire "controlled."
Dave Bunnell	1	The firing pattern in steep slopes & relatively heavy discontinuous fuel configurations requires concise, but flexible ignition patterns to reduce risk of escape.
Phil Anderson	4	Most burning is understory or for range improvement. Ignitions is not critical to obtain goal.
Bill Fischer	1	No comment
John Chapman	2	Since fire lines are not contructed to limit spread & only natural fuel breaks are used. ignition patterns & timing become critical to success.
Gary Meyer	1	One of the main ways to manage a prescribed burn.

Comments On Use of Firing Patterns

Broken Out By Agency

Respondent's Name	1=Always 2=Mostly 3=Sometimes 4=Rarely	Remarks
Jim Burdick	3	Most burns are piled fuels and ignition patterns are not important.
Ron McDonald	2	Depending on size of area, complexity of burn, desired objective, etc.
Mick Harrington	2	On initial research burns during high fire behavior, the ignition techniques determine crown damage. On repeat burns with light fuels the techniques often determine if a fire will carry
Ron Coats	2	Will vary from strip head to backing, depending on results from test burn.`
Jim Lunsford	1	Mostly use strip head fire, also lots of backing fire.
Fritz Cahill	1	To prevent escapes and minimize smoke production in sensitive areas.
Gary Biehl	1	Key to any prescription
Wallace Huff	1	Control intensity for control of escapes and achieve objectives. Need adjustment in fire behavior based on different ignition patterns. Current model (SPREAD) limits Rx applications.
Jack Kriesl	1	No Comment
Donald Carlton	1	We rarely just "throw fire" at a unit - we always have a planned ignition sequence.
Al Braddock	1	All fires are ignited to provide the desired level of intensity to accomplish objectives. The ignition pattern used is a function of the weather and terrain on a given burn block.
BOB KENNEY	2	I use ignition patterns to control intensities and rate of spread for both hand burns and helitorch.
LEROY WELS	2	NO COMMENT
R. Gordon Schmidt	2	Usually in the use of decks to assure draw - also, topography dictates pattern.
Clinton K. Sykes	2	Vary techniques to keep fire within prescription
Al Roberts	1	No Comment
Dave Bacon	1	Head strip fire, backing fire, and center fires are used in slash and under burns.
George J. Thiesen	1	No Comments
Jerry Williams	2	Unit size sometimes limits effective manipulation.
Bill Chapel	1	This in one of our keys to success.
George Curtis	1	This is usually the dey to make the fire behavior accomplish your objective.

** Administrative Agency : FWS

Respondent's Name	Rating	Remarks
Ward Feurt	1	Prescriptions include ignition pattern.
Calvin Gale	3	Where necessary for heavy fuel volume reduction, ignition patterns are used to manipulate behavior.
Frank Cole	1	A principal objective is to create a mosaic of bunred, unburned burn intensity areas for wildlife habitat.

Comments On Use of Firing Patterns

Broken Out By Agency

Respondent's Name	1=Always 2=Mostly 3=Sometimes 4=Rarely	Remarks
** Administrative Agency : NPS		
Robert F. Doren	1	We use head, flank, backing ifres and ignite in ???? patterns for smoke mgmt, fire intensity and rates of spread.
Rod Norum	2	No Comment
DAVID McHUGH	1	I like to burn with long flanking fires - develops good heat and duration.
WILLIAM B. CELLA	1	Ignition pattern is used continually to manipulate fire behavior of highly flammable black spruce fuels. Burn units are fairly close to areas of inhabited structures.
Paul Broyles	2	Manipulate intensities for two fuel types.
Jan van Wagtendonk	1	Behavior is controlled by ignition pattern.
Bruce L. Freet	2	Most prescribed burns are for hazard fuel reduction around or near structures and higways.
** Administrative Agency : PRIV		
Chuck Bushey	2	The only time your pattern doesn't influence fire behavior is from a spot fire outside.
Mark Hietlinger	1	We always consider ignition pattern relative to burn duration, smoke, windshift potential, flame length and rate of spread.
** Administrative Agency : STATE		
Wayne Mitchell	1	Ignition pattern is used to speed up or slow down the firing to meet the conditions of the day.
Duane Dupor	3	We conduct burns for various objective, on some fire manipulation is necsarry i.e. fuel reduction and others i.e. grass-wildlife burns it is not.
George Meadows	2	No Comment
Scott Heather	1	User perimeter ignition to draw the fire to the center for better control.
Hugh Ryan	1	Main determining factor after prescription is met.
Ed Matthews	1	No comment
David Dalrymple	2	Primarily to prevent escape and achieve desired results.
Royal Burnett	1	Most burns are oak-woodland or broadleaf bursh spieces - backburn vs headfires are utilized to manipulate intensity.
JOHN CRUMB	1	NO COMMENT
JOHN SHEPARD	2	Method and ignition pattern are used to modify heat release of the burn, depending on the burn objectives.

Comments On Use of Firing Patterns

Broken Out By Agency

Respondent's Name	1=Always 2=Mostly 3=Sometimes 4=Rarely	Remarks
** Administrative Agency : UNIV		
Leon Newenschwander	1	The use of topgraphy and fuel concentrations. We also use many different patterns depending on the situation.
Phil Omi	2	Agency generally will dictate pattern to be used.
Stew Pickford	0	no comment

Comments on Need of WINDOW System

Broken Out By Agency

Respondents' Name	1=Great Need 2=Some Need 3=Not Needed 4=Not Sure	Remarks
** Administrative Agency : BIA		
Jim Roessler	1	Will save time and may assist fire person in explaining other "resource mgrs" apecific fire behavior for given fire objectives in a shortened form.
Ralan Hartzell	4	Windows vary for fuel models, conditions and what you will accept - I don't know if we know enough about weather to identifiy in advance when we can burn. We never have enough time.
** Administrative Agency : BLM		
Larry Taylor	3	Too hypothetical - fire effects knowledge is not sufficient.
Bob Clark	1	Would save time (compared to the trial & error method now used) and be a super training tool.
Mike Fisher	1	It would be less time consuming to input what fire behavior we want and have the 'window' given to the manager.
Bill Casey	2	It has not been fully explained to me yet.
Melanie Miller	1	Would save alot of BEHAVE runs.
Greg Zschaechner	1	It would provide a means for us to comparte previous used prescriptions and posiibly find tune them.
Philo Parks	1	No comment
Rob Raper	1	Simplicity. It would get another tool to the field to meet resource objectives.
Carl St. Clair	1	Will assist in developing prescriptions to meet desired fire effects.
Walt Schopfer	1	No Comment
Phil Range	1	No comment
** Administrative Agency : FS		
R. Lynn Marsalis	1	Would help in planning. Would have a better handle on options.
Jim Webb	1	Will reduce planning time & improve understanding of BEHAVE outputs.
Dave Thomas	2	No comment
Dave Bunnell	1	The data must be available to process in a format that accepts fuel as heat sinks and accepts inputs for more than one flaming fire front.
Phil Anderson	1	No Comment
Bill Fischer	2	Need is greater for reatively inexperienced burner and as training tool to demonstrate basic relationships between fire behavior and environmental parameters.
John Chapman	1	Have a program package that was user friendly could speed up window development, but there are several programs that can be used to develop & test prescriptions now (BEHAVE, HP-71B).

Comments on Need of WINDOW System

Broken Out By Agency

Respondents' Name	1=Great Need 2=Some Need 3=Not Needed 4=Not Sure	Remarks
Gary Meyer	1	Too much time is spent arriving at a prescription when technology could do the work for us.
Jim Burdick	1	Would make the job easier to build a prescription. The problem is writing the objective you want to meet.
Ron McDonald	4	There have been many programs and systems developed just for the sake of developing.
Mick Harrington	1	However, I don't think the fire behavior-effects relationships are precisely known. I think the fire manager will have a hard time accuately determining what fire behavior is desired.
Ron Coats	1	Would save a tremendous amount of time trying to find the 'range' that meets prescription parameters.
Jim Lunsford	1	But for different reason than you have explaind (see employee suggestion).
Fritz Cahill	2	Any new knowledge is helpful in the 'art' of Rx Burning.
Gary Biehl	2	No comment
Wallace Huff	1	Linking to fire effects and historical weather would be another tool for Rx fire mgrs.
Jack Kriesl	4	Not sure what this is.
Donald Carlton	2	Need link to NFWDL and change of NFWDL to allow more obs/day
Al Braddock	2	No Comment
BOB KENNEY	1	I think it will help be to get the matrix I need.
LEROY WELS	2	NO COMMENT
R. Gordon Schmidt	1	No comment
Clinton K. Sykes	2	No
Al Roberts	2	Can provide some guides.
Dave Bacon	1	If we could plug in weather and fuels data, then get back if we would meet burn objectives.
George J. Thiesen	1	It would be an asset in court cases.
Jerry Williams	0	
Bill Chapel	1	I don't feel we really have a system that puts it all together. I hope to have WINDOW use the same material and marry it all together for one system output.
George Curtis	1	Must be broad or wide to reach in a timely manner. (??)

** Administrative Agency : FWS

Ward Feurt	1	Reverse the order. Good approach.
Calvin Gale	1	In a time of reduced funding & personnel levels, experience will wane and this may help fill the void.

Comments on Need of WINDOW System

Broken Out By Agency

Respondents' Name	1=Great Need 2=Some Need 3=Not Needed 4=Not Sure	Remarks
Frank Cole	4	No comment
** Administrative Agency : NPS		
Robert F. Doren	1	I've already turned the BEHAVE use backwards to do this.
Rod Norum	1	We have the tools but is sort of becomes the 'agony of the chase' to pull it together. More steps = more errors.
DAVID McHUGH	2	Can provide some mbasic measures but requires interpretation.
WILLIAM B. CELLA	1	It is the next logical step for developing an integrated system for fire mgmt.
Paul Broyles	1	Will save a hell of lot of "finger-punching" time and guesswork. Would love to have it available.
Jan van Wagtendonk	2	We can do the job without it but it would be nice to have.
Bruce L. Freet	2	User have to trained to understand it, recognize what questions need to be asked, and have ability to the computer & program. Few have those talents.
** Administrative Agency : PRIV		
Chuck Bushey	1	If it was available I would use it!
Mark Hietlinger	2	The tables we used (see example) make it pretty easy to work backwords.
** Administrative Agency : STATE		
Wayne Mitchell	1	I agree that presciptions should be created based on land mgmt objectives.
Duane Dupor	4	I don't know enough of it to make a judgement.
George Meadows	1	No Comment
Scott Heather	1	There is nothing currently available.
Hugh Ryan	2	Great need if you can get fire effects on target.
Ed Matthews	2	Would improve our capabilities in prescribed fire planning.
David Dalrymple	1	No comment
Royal Burnett	2	Possible need when moving into new fuel types.
JOHN CRUMB	1	WOULD SPEED UP PRESCRIPTION DEVELOPMENT.
JOHN SHEPARD	1	Any tool that will alllow mo~~r~~re burning days to be identified and used is greatly needed. Rx burning needs are expanding and we need to expand our burning windows.
** Administrative Agency : UNIV		
Leon Newenschwander	1	This depends on the product.
Phil Omi	1	Good planning tool. I've attemped related approach with BRNPLAN.

APPENDIX C

USDA-FOREST SERVICE

COMPUTATION SHEET

SHEET ________ OF ________

MADE BY *[initials]*

CHECKED BY 10/30/86 (INITIAL AND DATE)

Subject:

Given: fuel model

U = wind, ft/min $\Rightarrow \phi_W$

$\tan\theta$ = slope $\Rightarrow \phi_S$

ω = dir. of wind vector

θ = dir of spread calc. $\Rightarrow \alpha', \alpha'+90, \alpha'+180$

Find

α = dir. of max spread

$(U_E)_\theta$ = eff wind in direction θ

$$W = R_0 \phi_W$$
$$S = R_0 \phi_S$$

$$X = R_0 \phi_S + R_0 \phi_W \cos\omega$$
$$Y = R_0 \phi_W \sin\omega$$

$$\underbrace{(X^2+Y^2)^{1/2}}\; = R_0 \underbrace{\left[(\phi_S + \phi_W \cos\omega)^2 + (\phi_W \sin\omega)^2 \right]^{1/2}}_{\downarrow}$$

$$R_x = R_0 \left[1 + \quad \downarrow \quad \right]$$

$$\Rightarrow (\phi_E)_x = \cancel{1+} \left[(\phi_S + \phi_W \cos\omega)^2 + (\phi_W \sin\omega)^2 \right]^{1/2} \cancel{-1}$$

$(EW)_x =$

$$(\phi_E)_\theta = R_\theta / R_0 - 1$$

$$R_\theta = R_x (1-e) / (1 - \epsilon \cos\theta')$$

$$\frac{R_\theta}{R_0} = \frac{\cancel{R_0}}{\cancel{R_0}} \underbrace{\left[1 + \left[(\phi_S + \phi_W \cos\omega)^2 + (\phi_W \sin\omega)^2 \right]^{1/2} \right] \left[\frac{(1-e)}{(1-\epsilon\cos\theta')} \right]}$$

$$\Rightarrow (\phi_E)_\theta = -1 +$$

$$= -1. + \left[\frac{1-e}{1-e \cdot \cos(\phi)} \right] + \left[(\phi_S + \phi_W \cos(\omega))^2 + (\phi_W \cdot \sin(\omega))^2 \right]^{1/2} \cdot \left[\frac{1-e}{1-e \cdot \cos(\phi)} \right]$$

~~7100-71~~ (7/68)

$$= -1. + \left[\frac{1-e}{1-e \cdot \cos(\phi)} \right] + \left[(\phi_e)_x \right] \cdot \left[\frac{1-\epsilon}{1-\epsilon \cdot \cos(\phi)} \right]$$

USDA-FOREST SERVICE

COMPUTATION SHEET

SHEET .... OF ....

MADE BY ....

CHECKED BY ....
(INITIAL AND DATE)

Subject:

$$\Rightarrow \delta' = \sin^{-1}\left\{ \frac{\left|\cancel{R_0}\, Q_w \sin\omega\right|}{\cancel{R_0}\left[(P_0 + Q_w\cos\omega)^2 + (Q_w \sin\omega)^2\right]^{1/2}} \right\}$$